Intercomparison of cloud model simulations of Arctic mixed-phase boundary layer clouds observed during SHEBA/FIRE-ACE: Lessons learned

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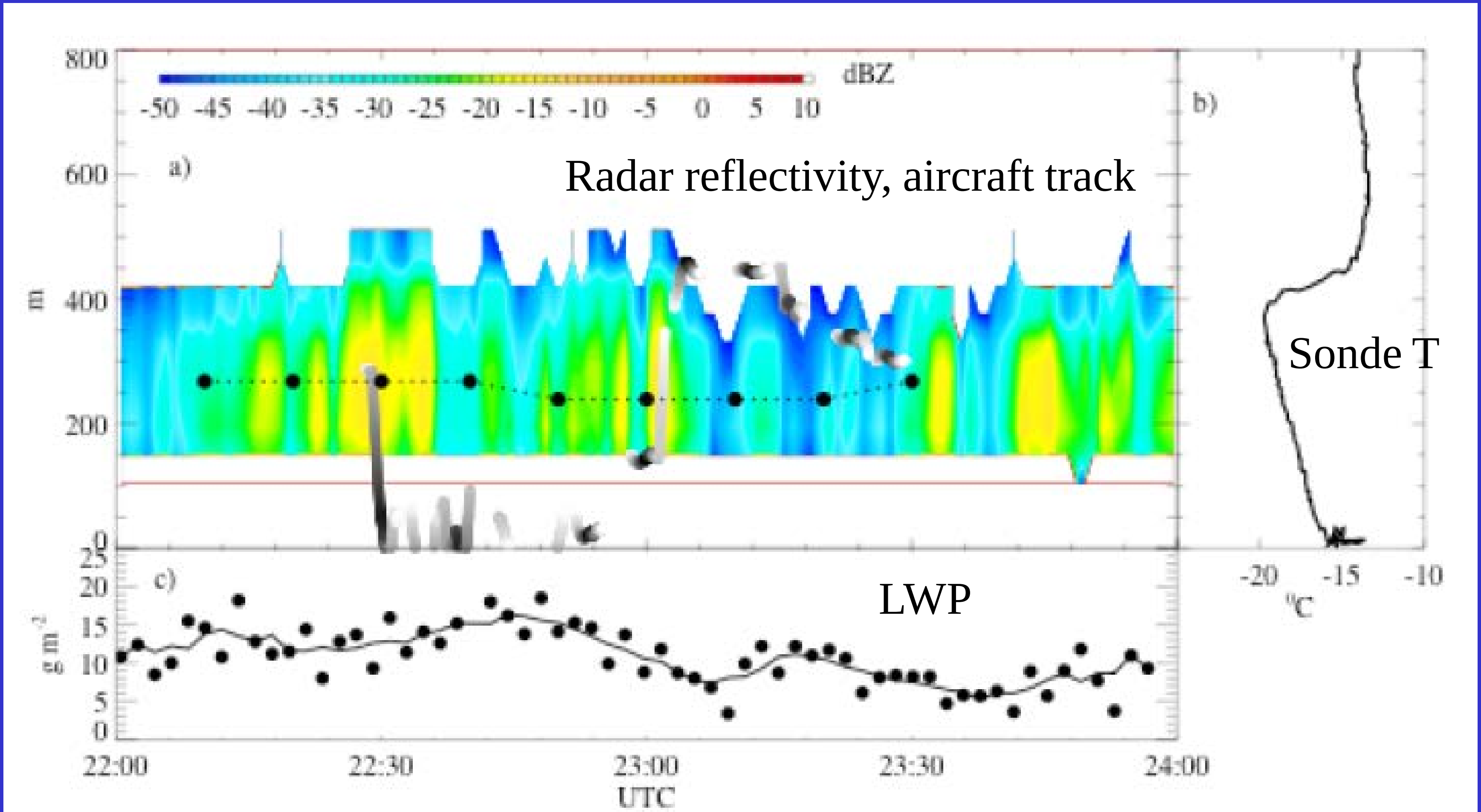
ASR STM, ISDAC Breakout, March 29, 2011

7 May, 1998 Case Study



From P. Zuidema

- This case builds upon the previous ARM/GCSS model intercomparison from MPACE.

- Several key differences from MPACE cases:
  - Colder temperatures (~ -22 C vs. -15 C)
  - Much smaller surface turbulent heat fluxes (ice-covered vs. open ocean)
  - More polluted aerosol
  - Much smaller amounts of cloud liquid water

Goals

- Document ability of models to simulate thin mixed-phase clouds for conditions much different than MPACE (more similar to ISDAC cases but much colder)

- Investigate causes of model differences through process-based analysis.

- Key issues:
    - Longevity of mixed-phase clouds in simulations, partitioning of liquid and ice, impact on surface radiative fluxes
    - Sensitivity to concentration of ice crystals

Participating LES/cloud models

-SAM-PNNL (Jiwen Fan, Mikhail Ovtchinnikov)

(2D, Δx = 100 m, Bin microphysics)

-DHARMA (Ann Fridlind, Andrew Ackerman)

(3D, Δx = 50 m, Bin microphysics)

-NMS-SHIPS (Gijs de Boer, Tempei Hashino)

(2D, Δx = 100 m, Bin microphysics)

-METO-LEM (Ben Shipway)

(3D, Δx = 50 m, 2-moment Bulk microphysics)

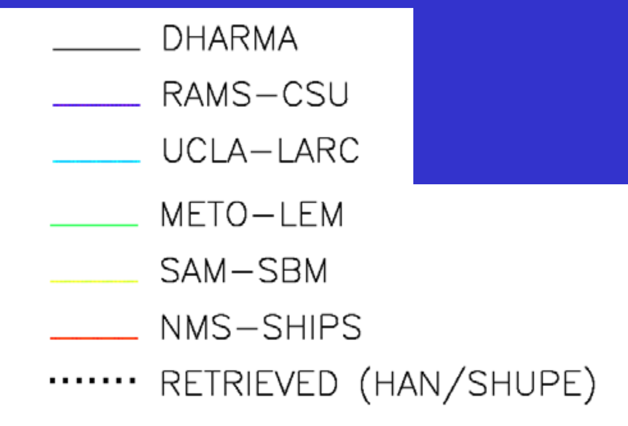
-UCLA-LARC (Yali Luo)

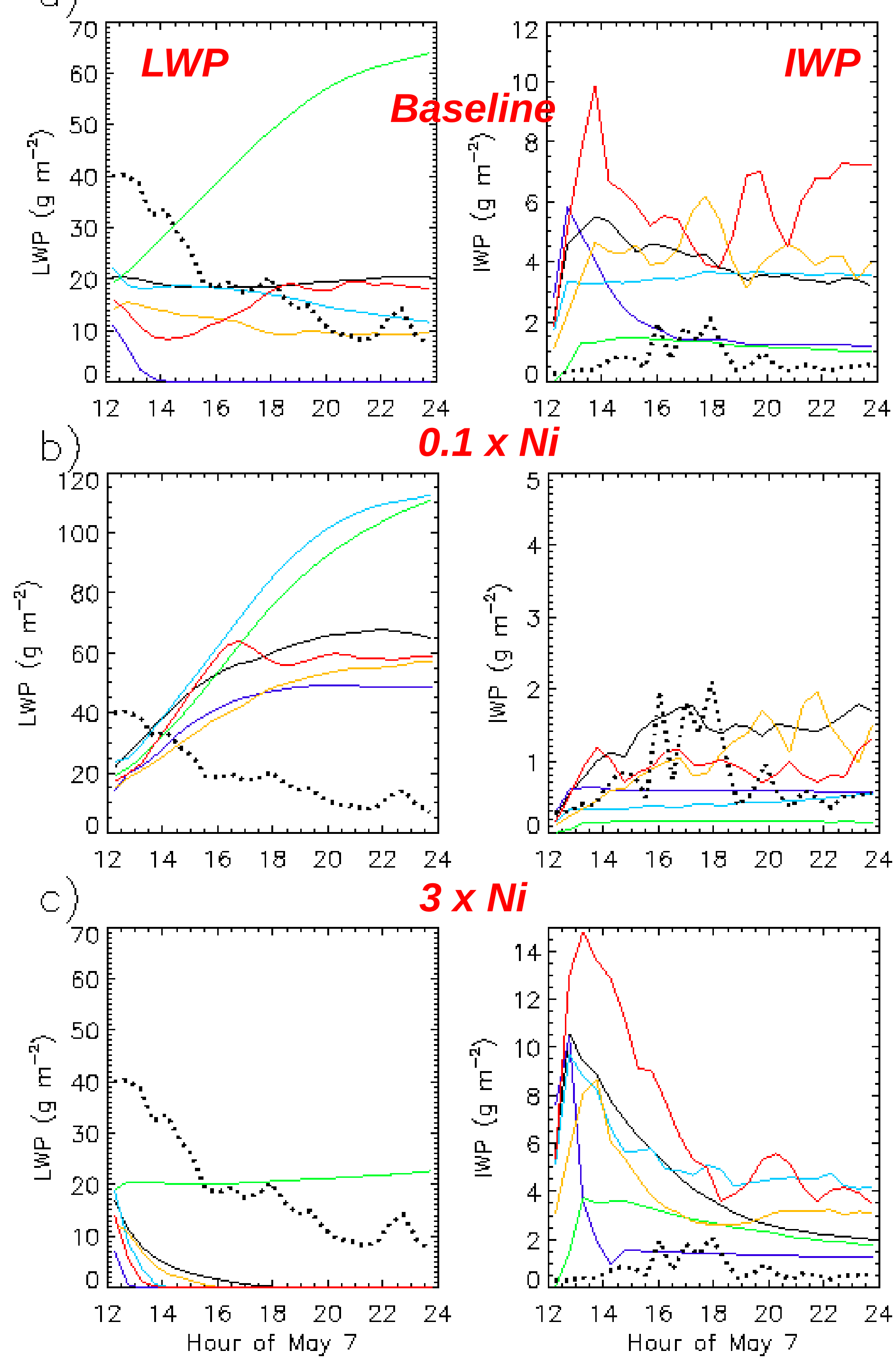
(2D, Δx = 1000 m, 2-moment Bulk microphysics)

-RAMS-CSU (Alex Avramov, Jerry Harrington)

(2D, Δx = 1000 m, 2-moment Bulk microphysics)

Timeseries of LWP and IWP

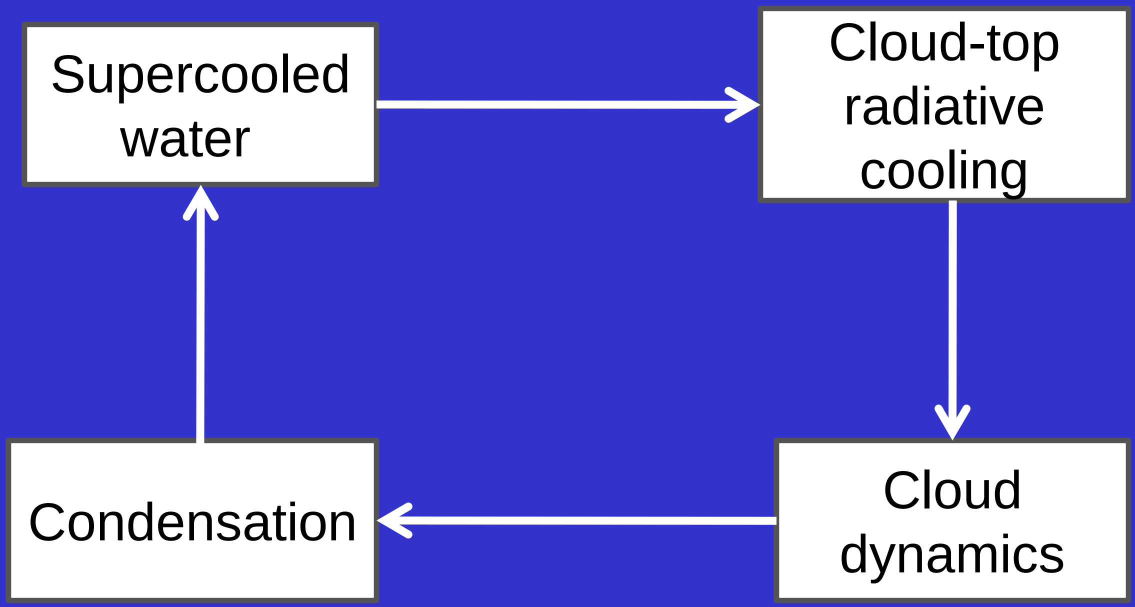


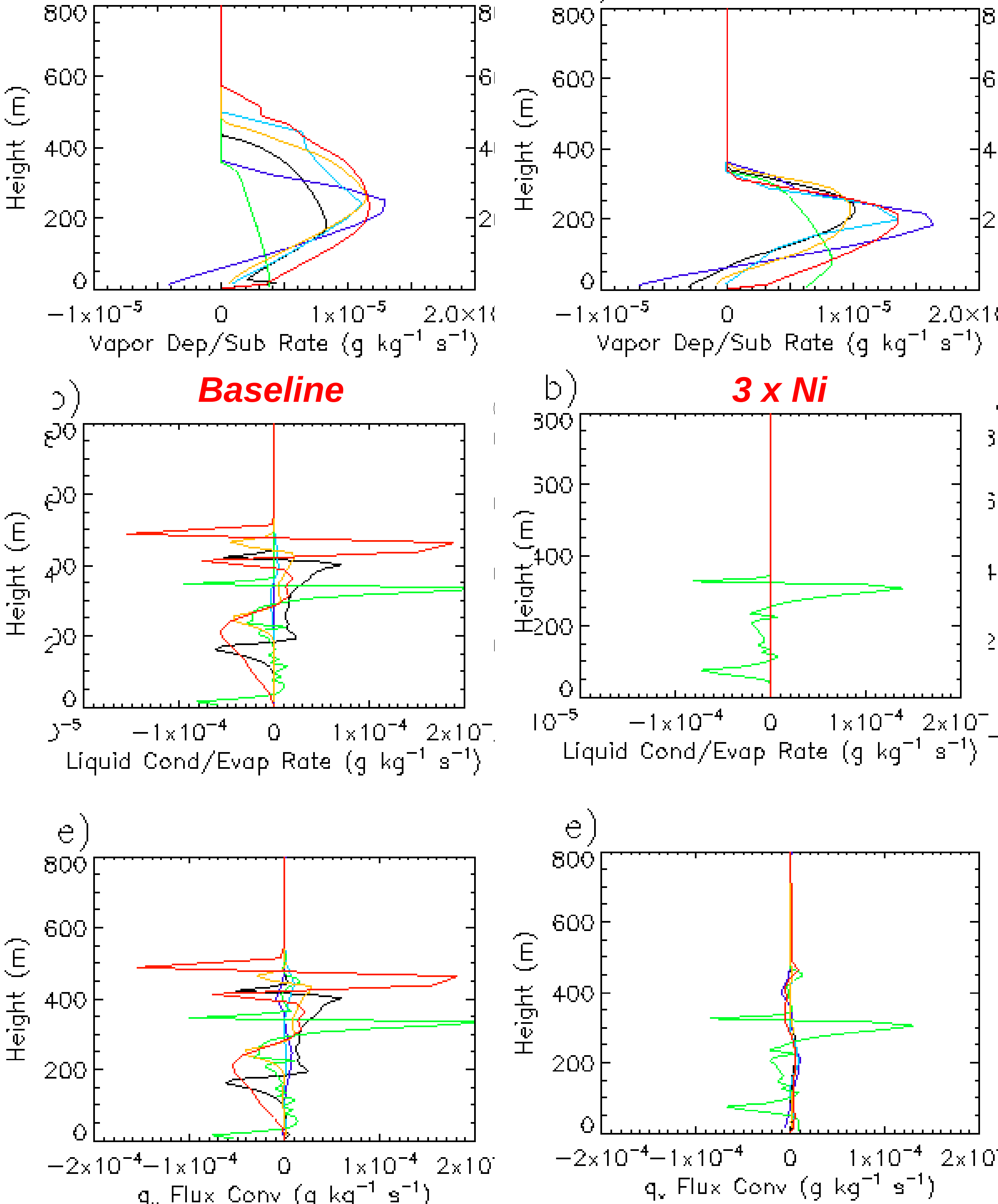


Overall, simulations tend to group into two quasi-steady states within the first few hours: 1) peristent mixed-phase cloud, 2) radiative-weak all-ice cloud → suggestion of multiple equilibrium states for these conditions?

These two states have dramatically different boundary layer thermodynamics, cloud top radiative cooling, turbulence/cloud dynamics, and surface radiative fluxes.

Persistent mixed-phase clouds were largely self-maintained in the simulations through a feedback between supercooled liquid water, cloud top radiative cooling, cloud dynamics, local water vapor convergence, and condensation.




Baseline
3 x Ni
b)
e)
e)
Height (m)
Vapor Dep/Sub Rate (g kg^{-1} s^{-1})
Liquid Cond/Evap Rate (g kg^{-1} s^{-1})
q_v Flux Conv (g kg^{-1} s^{-1})

Status: (currently in review in *JAMES*)

"Lessons learned":

- **There were large differences in cloud top radiative cooling even for similar cloud profiles → impact of RT schemes (use simple formula for RT calculations following BLCWG?)**

- **More complete set of diagnostics for boundary layer/turbulence (buoyancy fluxes, vertical velocity variance, entrainment, etc.)**

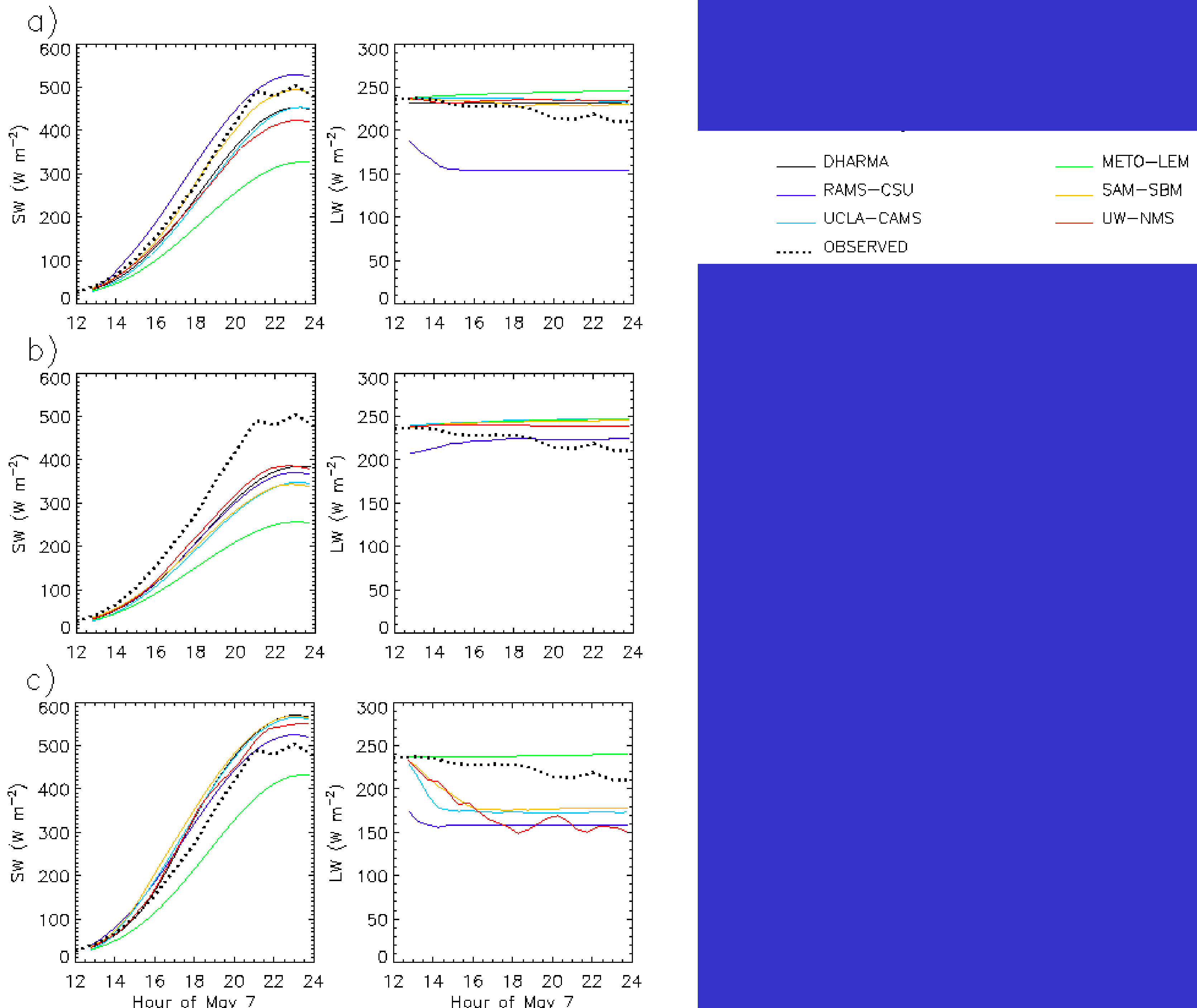
- **Impact of spinup (initialize with liquid, but allow dynamics to fully spin up before introducing ice)**

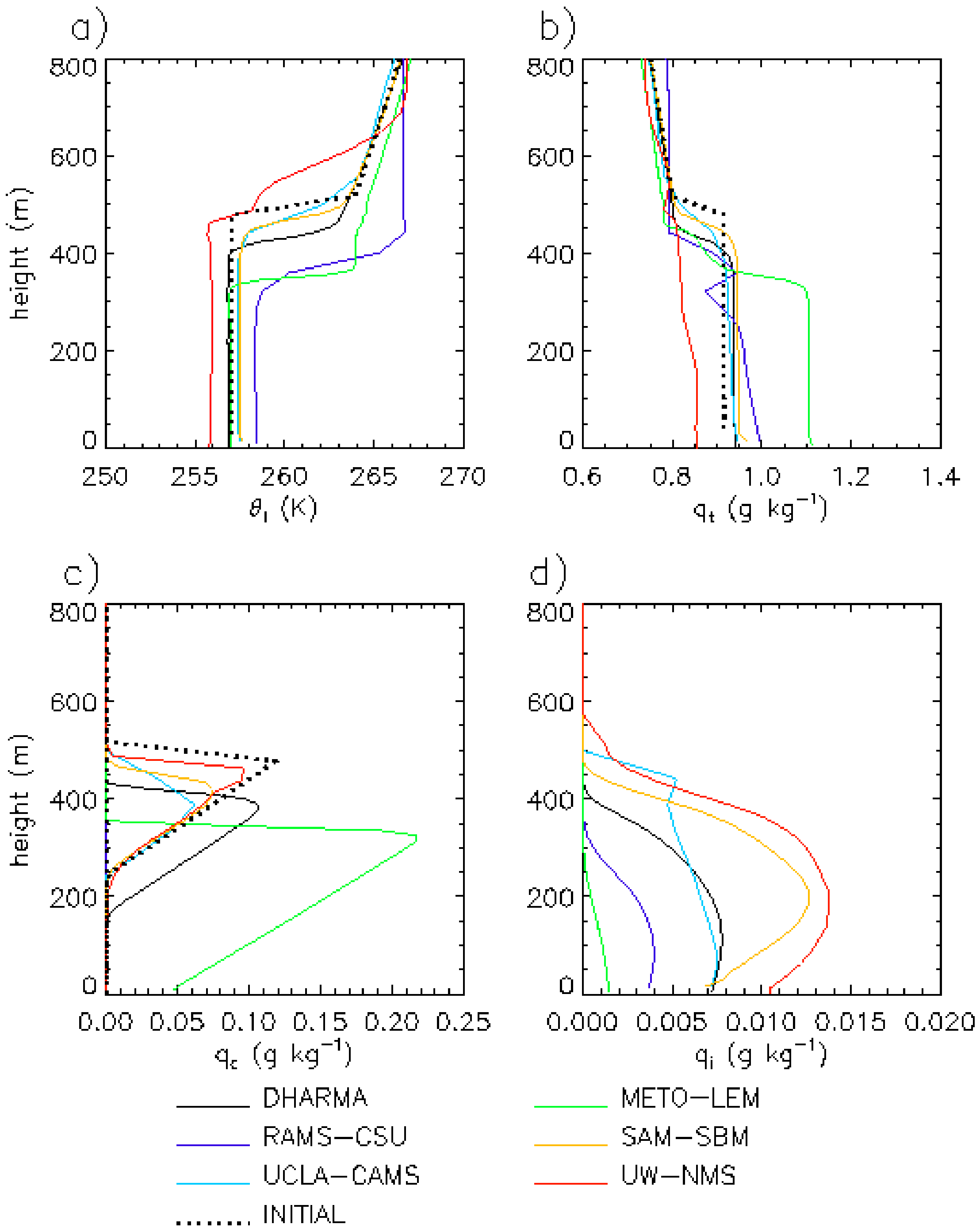
Some key questions:

- Given the importance of cloud-radiative-cloud dynamics feedback, what is the impact of horizontal and vertical grid spacing?

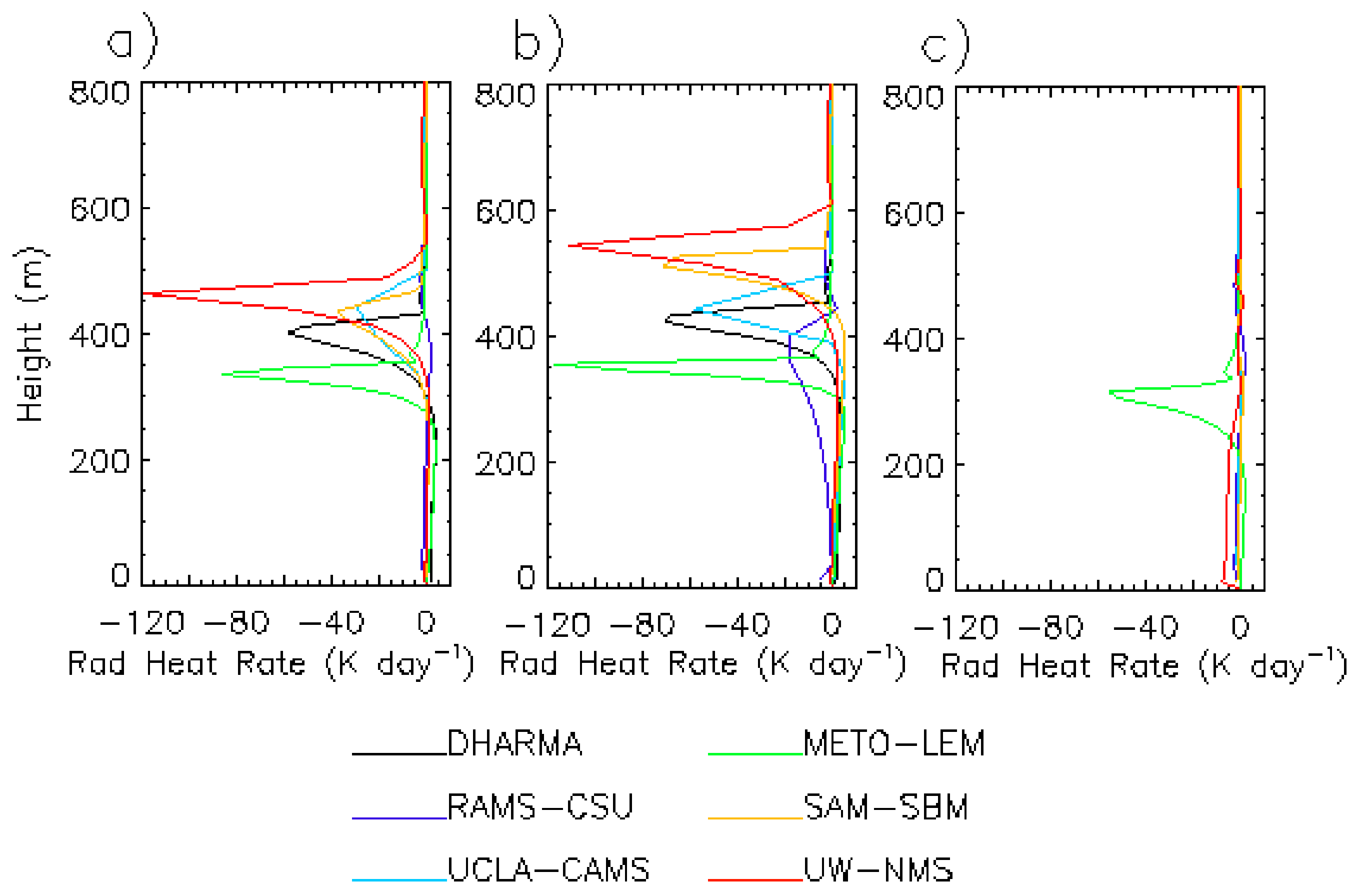
- What is the role of large-scale forcing? Can variations in large-scale forcing produce similar sensitivity (i.e., rapid collapse of the cloud layer) as changes in ice number concentration?

- How important are the cloud-radiative-dynamical feedbacks for cases with stronger surface forcing (e.g., MPACE)?


a)
b)
c)
SW (W m^{-2})
LW (W m^{-2})
Hour of May 7
DHARMA
RAMS−CSU
UCLA−CAMS
OBSERVED
METO−LEM
SAM−SBM
UW−NMS



a)
b)
c)
d)
height (m)
0
200
400
600
800
250
255
260
265
270
θ_l (K)
0.6
0.8
1.0
1.2
1.4
q_t (g kg^{-1})
0.00
0.05
0.10
0.15
0.20
0.25
q_c (g kg^{-1})
0.000
0.005
0.010
0.015
0.020
q_i (g kg^{-1})
DHARMA
RAMS−CSU
UCLA−CAMS
INITIAL
METO−LEM
SAM−SBM
UW−NMS


a)
b)
c)
Height (m)
800
600
400
200
0
−120 −80 −40 0
Rad Heat Rate (K day⁻¹)
DHARMA
METO−LEM
RAMS−CSU
SAM−SBM
UCLA−CAMS
UW−NMS